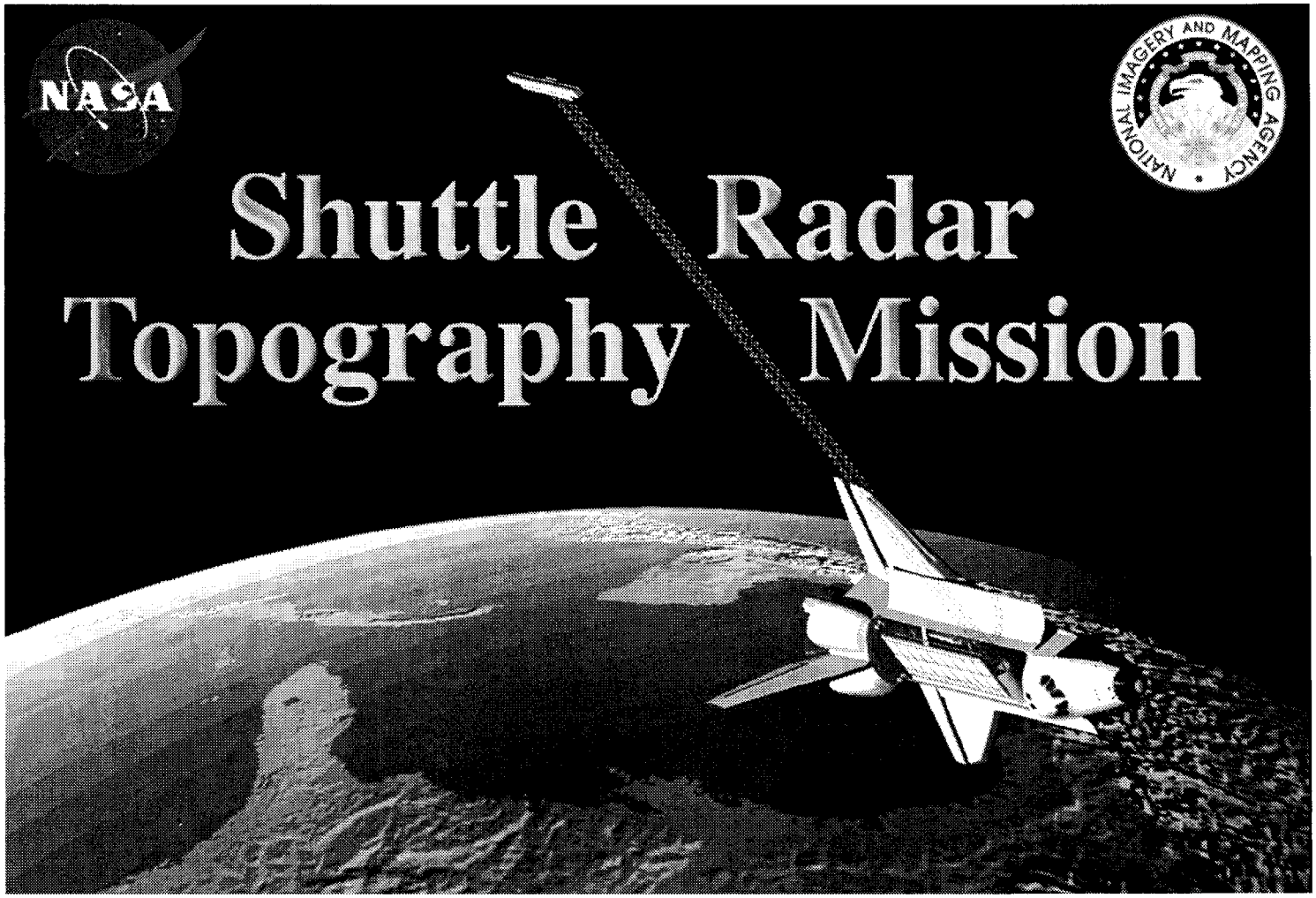
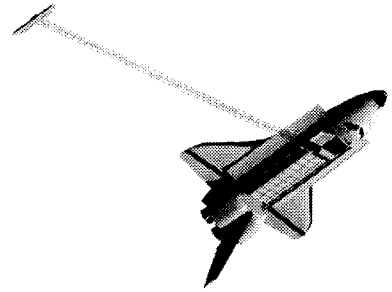


29 January 2000

Riley M. Duren
Sr. Member of Technical Staff
Jet Propulsion Laboratory
California Institute of Technology
riley.m.duren@jpl.nasa.gov
818-354-5753

Agenda



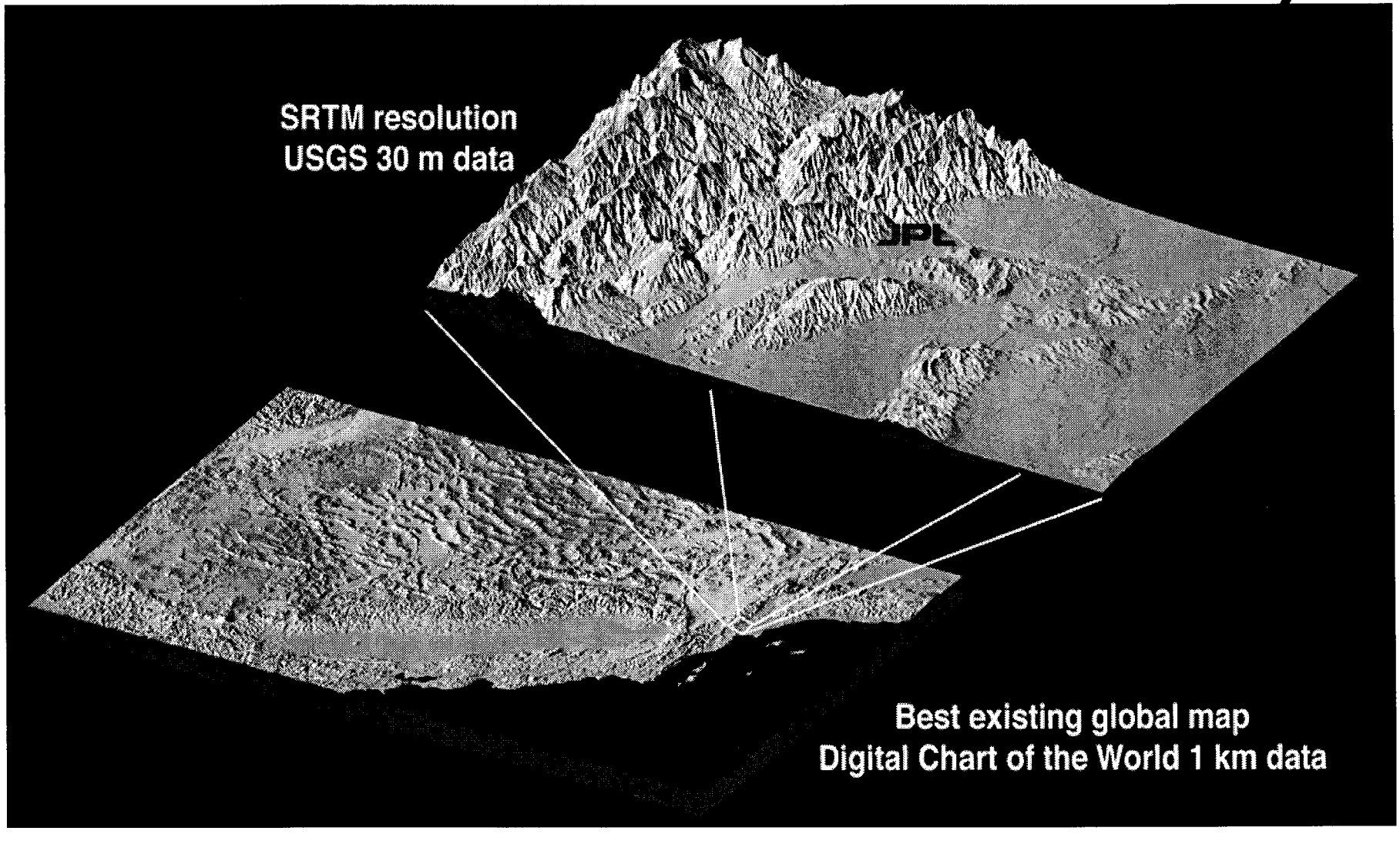
- Problem statement
- SRTM Programmatics
- Expected Coverage
- IFSAR Concepts & Theory of Operation
- System Overview
  - payload bay hardware
  - mast
  - outboard antenna
  - attitude & orbit determination avionics (AODA)
    - GPS receivers
    - metrology instruments
  - crew cabin equipment
- Mission Operations
- Summary

JPL DLR

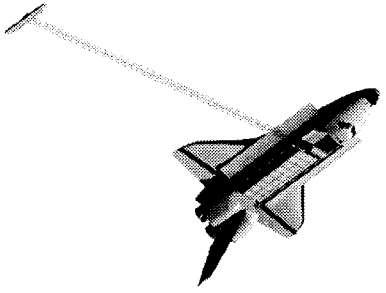
Shuttle Radar Topography Mission

Problem: We need better topo-maps!

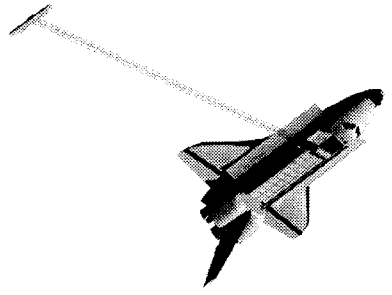
(we have better global maps of Venus than we do of Earth)



SRTM Programmatic Summary

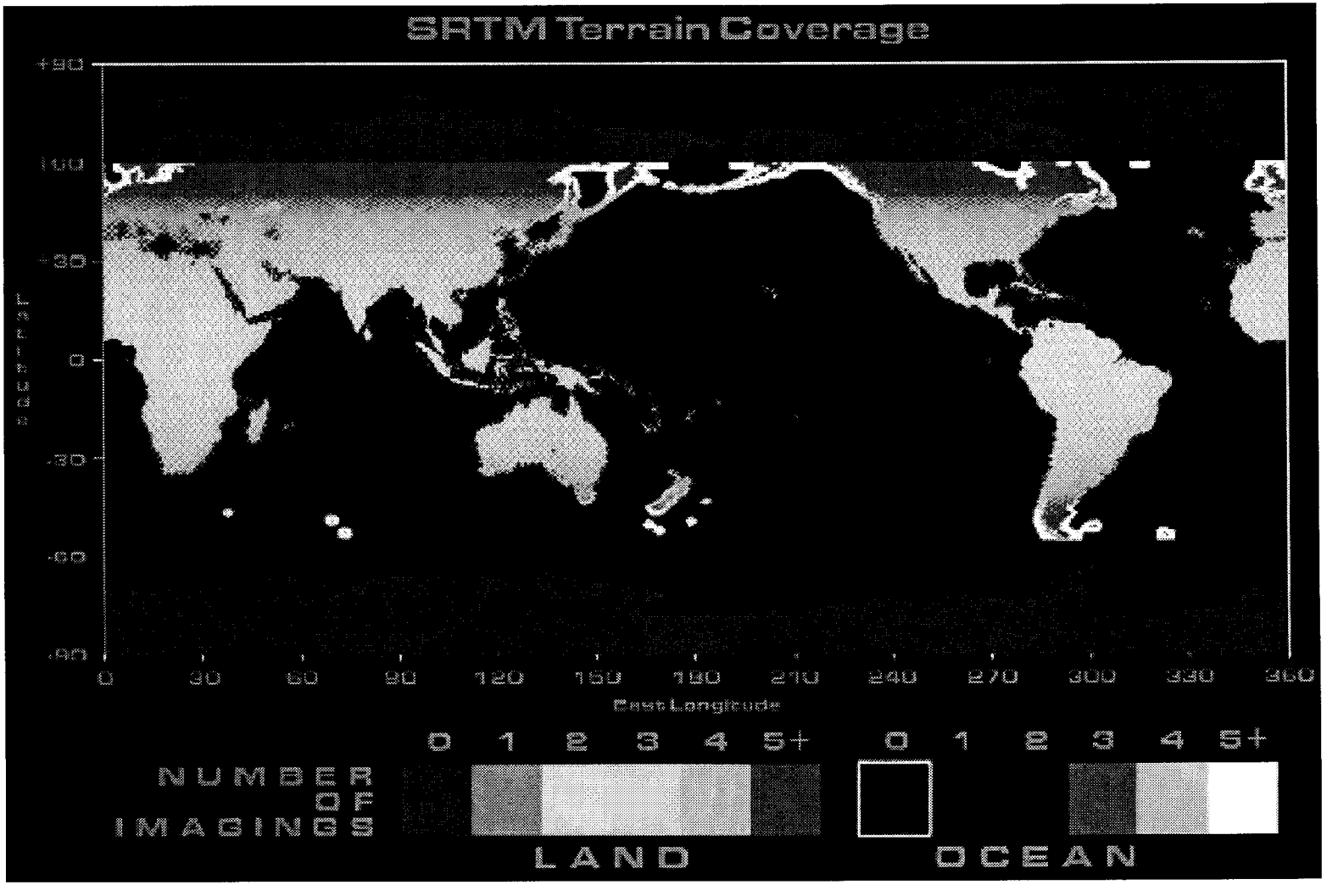


- **Mission Objectives**
  - acquire data over 80% of Earth's land mass (60 deg N to 58 deg S latitudes) and produce topographic products to ITHD-2 specifications
  - Interferometric Terrain Height Data (ITHD)-2 specifications: 30 m x 30 m spatial posting with ≤16 m absolute vertical (linear) accuracy and ≤10 m relative vertical accuracy at the 90% (1.6 σ) level
  - C-band will meet all of the above objectives; X-band will do the same except 6 m relative vertical accuracy and 32% coverage (50 km swath)
- **Sponsors**
  - NASA, National Imagery and Mapping Agency (NIMA, DoD), German Aerospace Center (DLR, Deutsches Zentrum fur Luft- und Raumfart e.V.)
- **Implementation**
  - Fixed Baseline Interferometric SAR (IFSAR) at two wavelengths (C- and X-band) (advantages vs. repeat pass interferometry)
  - Managed by JPL & DLR
  - 11-day shuttle mission to acquire global data set
  - 3 year development phase & 12 month data processing phase
  - Modified existing SIR-C/X-SAR hardware with the addition of 2nd channel to form an interferometric SAR (IFSAR)
  - New components including a 60 meter mast and metrology system added
  - Principle contractors: Dornier,Ball, AEC-ABLE, COI, ATC, LM, TBC, Leica

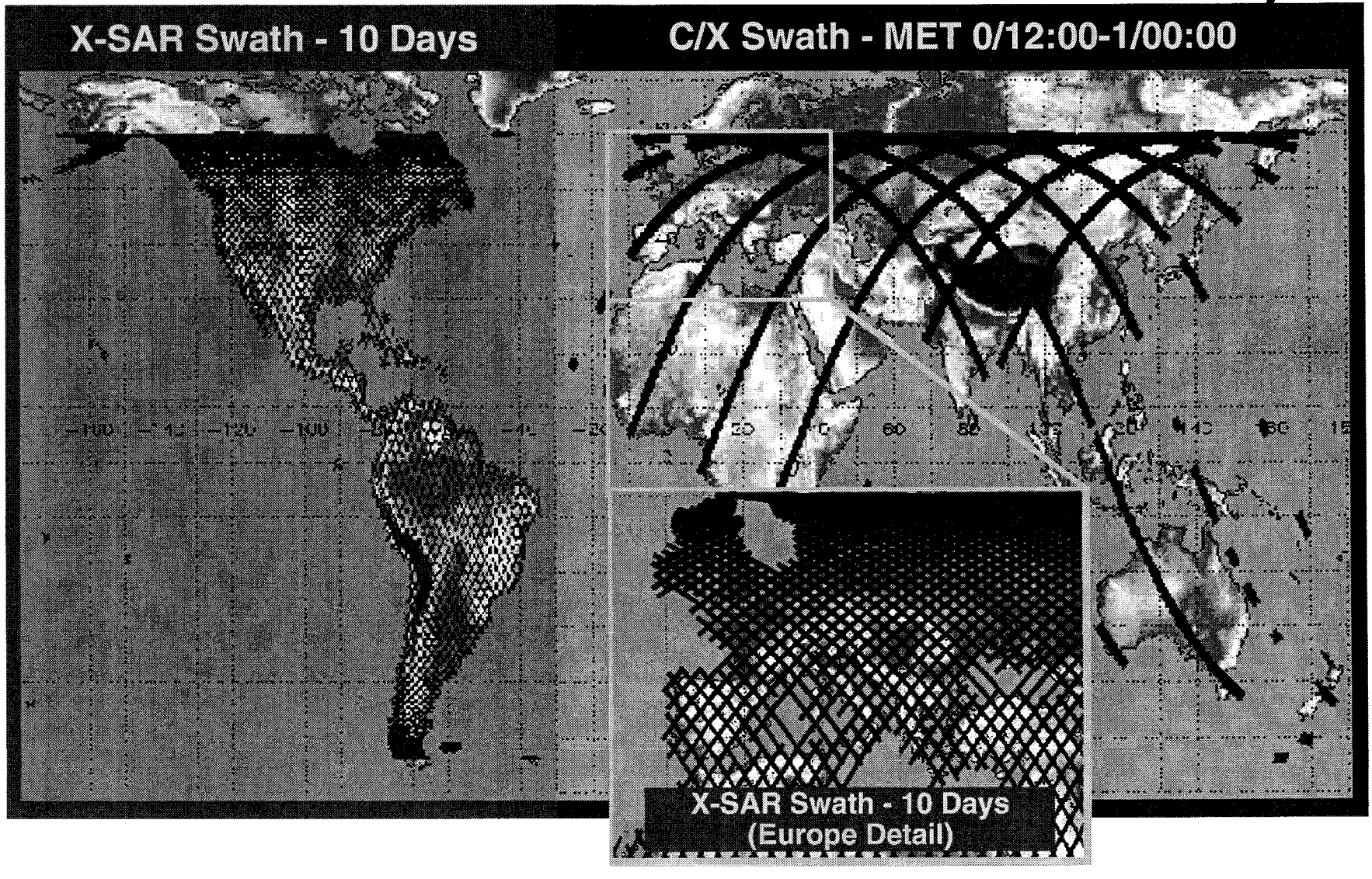


SRTM C-Band Ground Coverage

10-DAY MISSION; 159 ORBITS
(NOT INCLUDING CALIBRATION OCEAN DATATAKES)



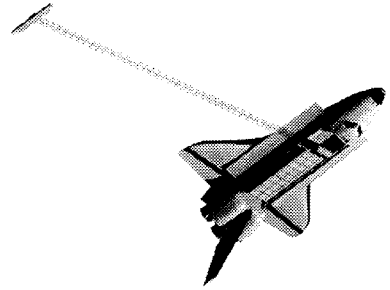
SRTM X-band Ground Coverage



JPL DLR

Shuttle Radar Topography Mission

SRTM Misc. Facts



- Cost: $141M

- Mass & Energy (BIG)
  - mass = 13, 600 kg (29,000 lbs or 14.5 tons)
  - energy = 900 KW-hours (80 hours of radar operation)

- Potential Data Uses
  - scientific: geology, hydrology (flood & lahar forecasting), volanic/seismic research, etc
  - commercial: aircraft navigation and ground proximity warning systems, land-use planning, cell phone tower placement, etc
  - military: flight simulators, logitistics planning, battlefield management

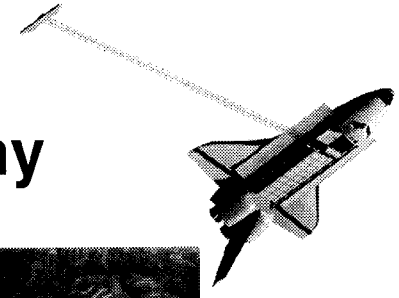
- Firsts
  - first fixed baseline, spaceborne IFSAR
  - largest rigid space structure (mast is about twice the length of the MIR space station)

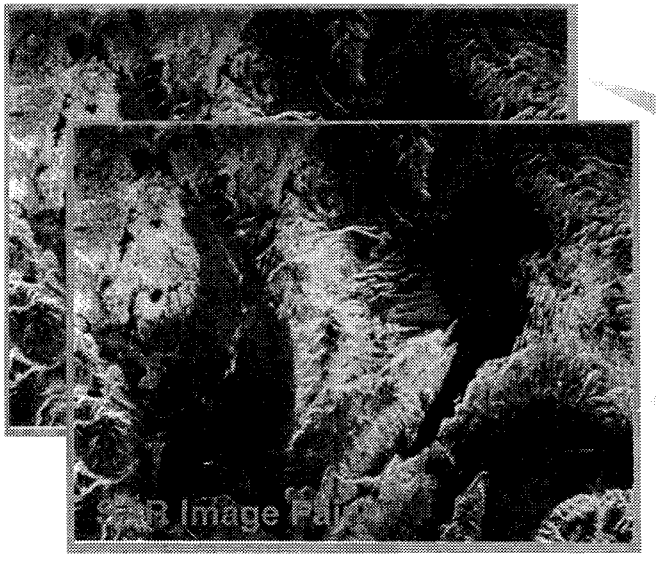
- Data Volume
  - 270 Mbps or 34 Mbytes per second (fill a 10 Gbyte hard-drive in 5 minutes)
  - 9.8 Tbytes total data volume (equivalent to 15,000 CD-ROMs - roughly equivalent to the US Library of Congress)

JPL DLR

Shuttle Radar Topography Mission

Using IFSAR to measure topography

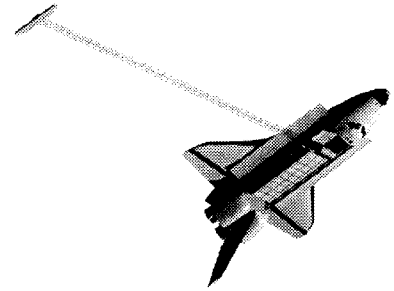


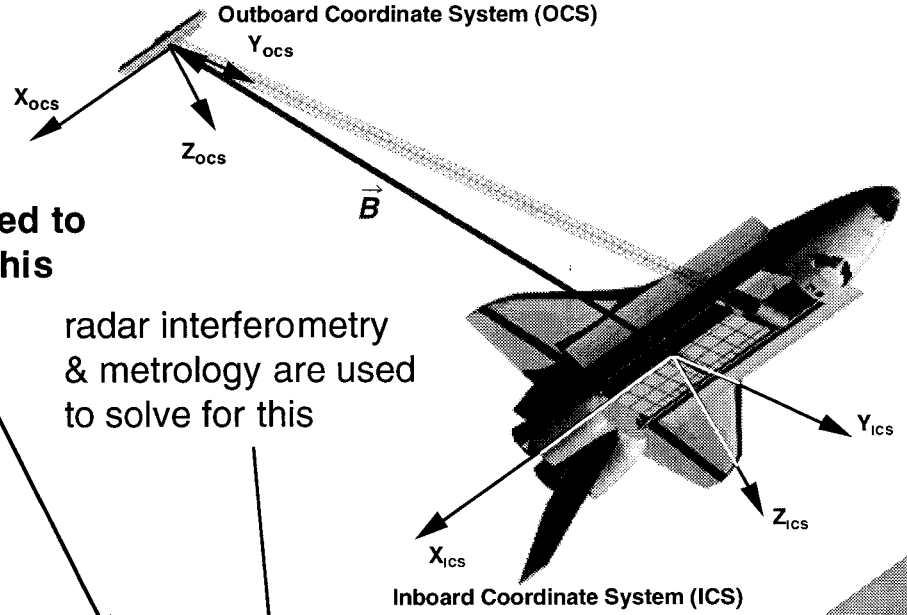


GPS &
Metrology

From SRL/SIR-C: LONG VALLEY, CALIFORNIA

Theory of Operation





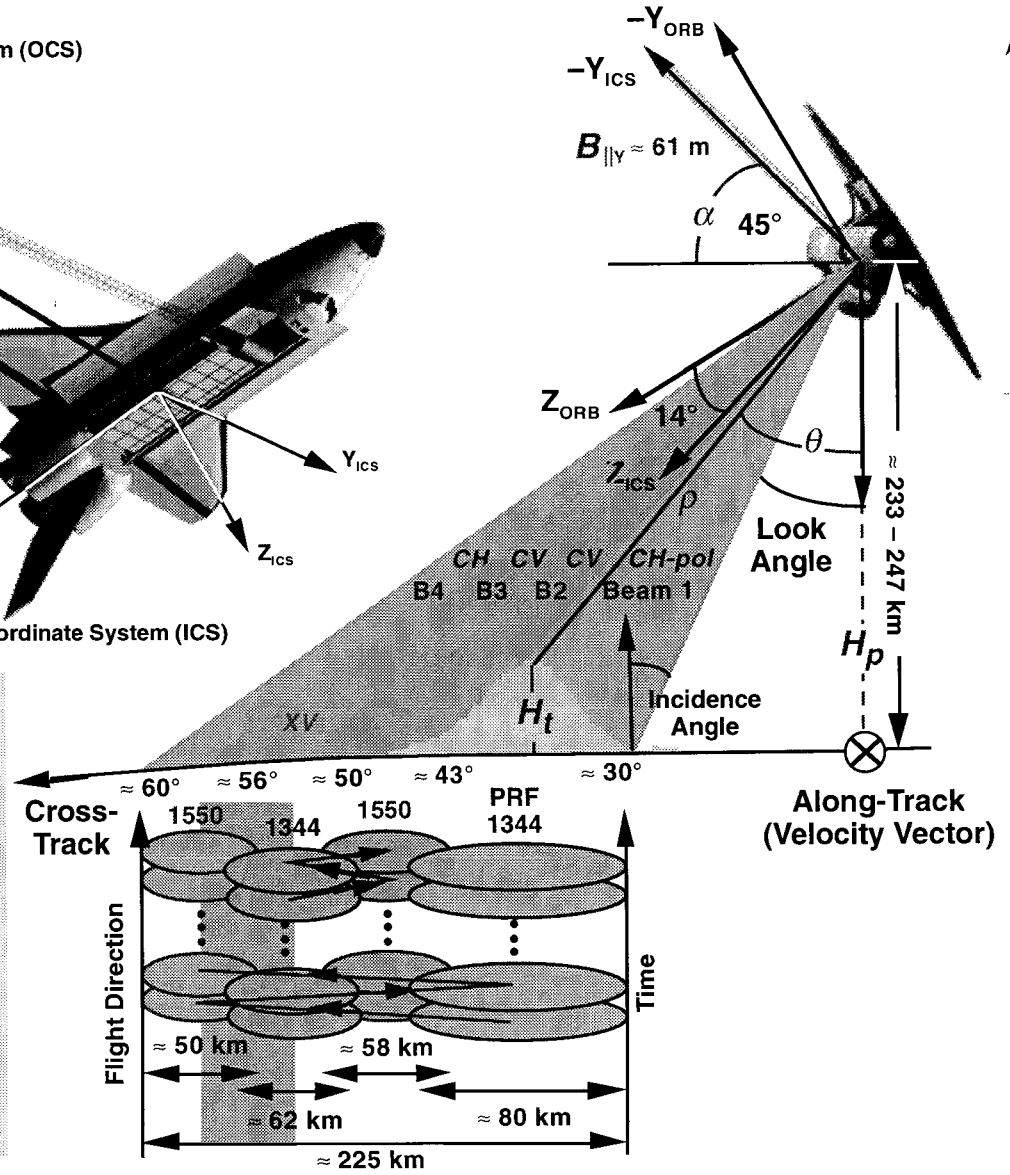
GPS is used to measure this

radar interferometry & metrology are used to solve for this

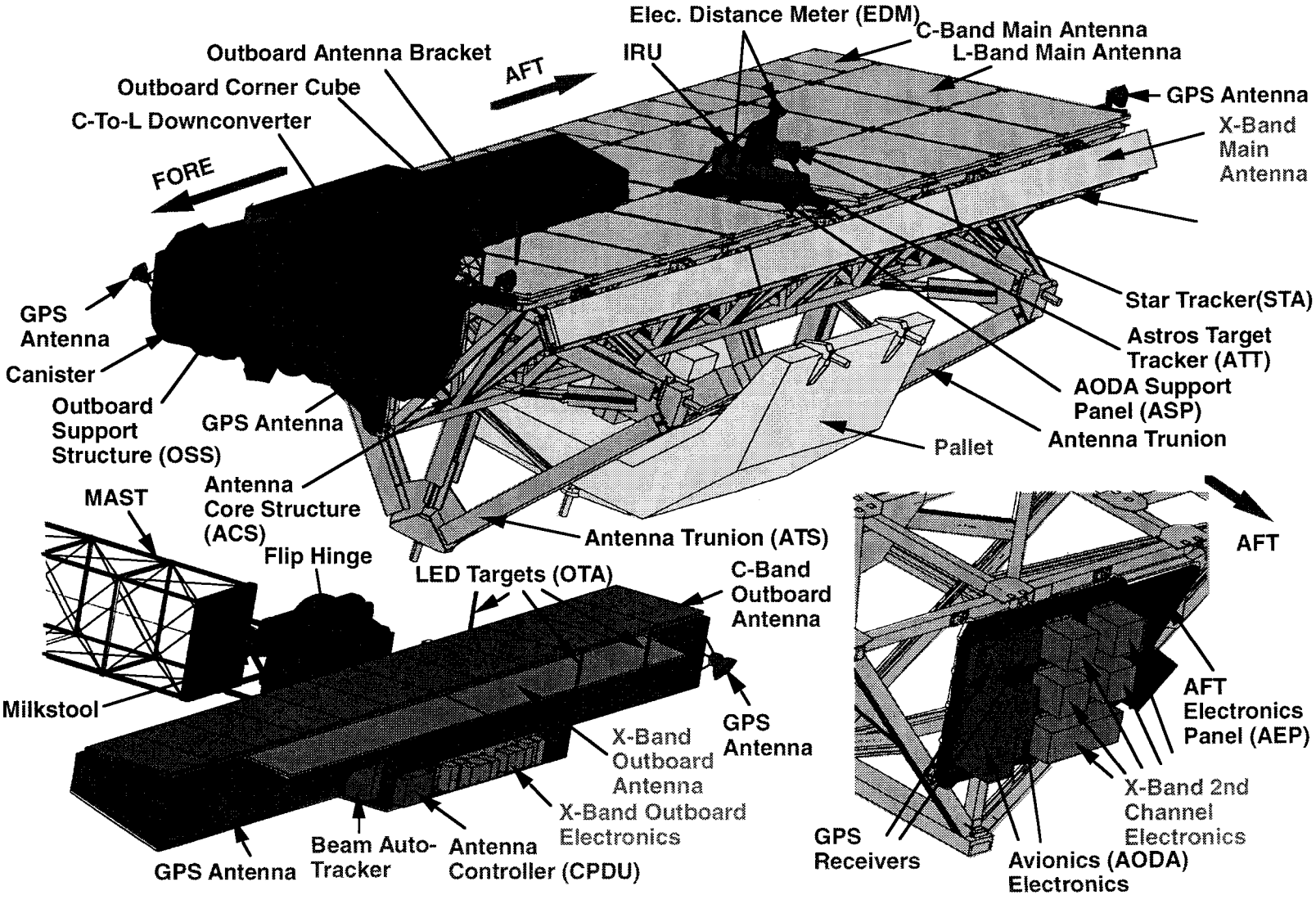
$$H_t \approx H_p - \rho \cos(\theta)$$

$$\theta \approx \alpha - \sin^{-1}(\phi \lambda / (2\pi B_{\|Y}))$$

- H_t : Target Height
- H_p : Platform Height
- ρ : Range to Target
- θ : Target Look Angle
- α : Baseline Angle
- ϕ : Interferometric Phase
- λ : Radar Wavelength
- $B_{\|Y}$: Baseline Length



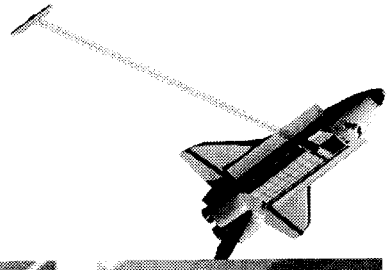
Payload Bay Hardware - I

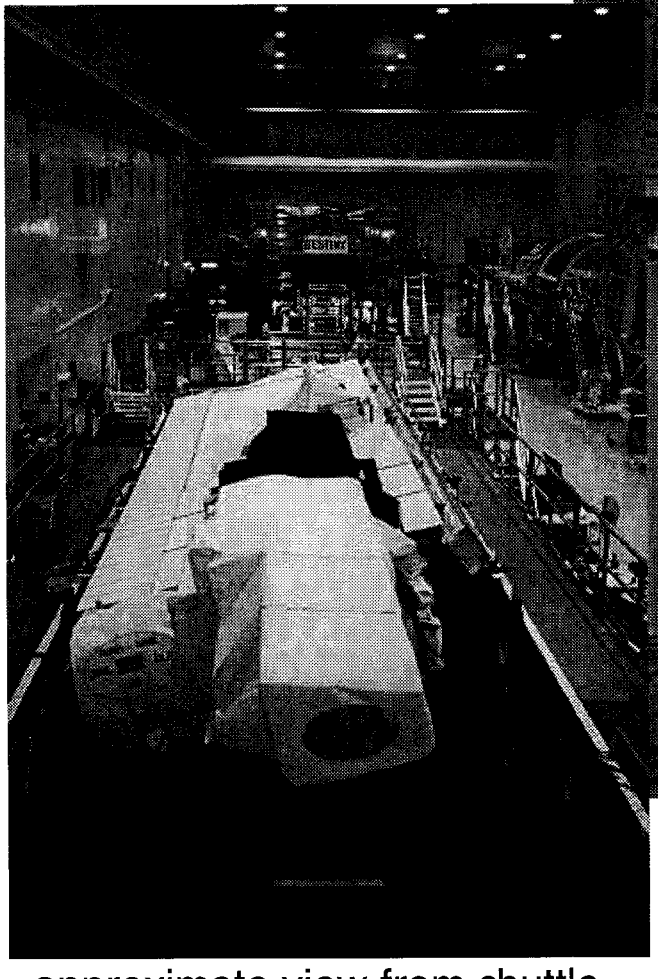


JPL DLR

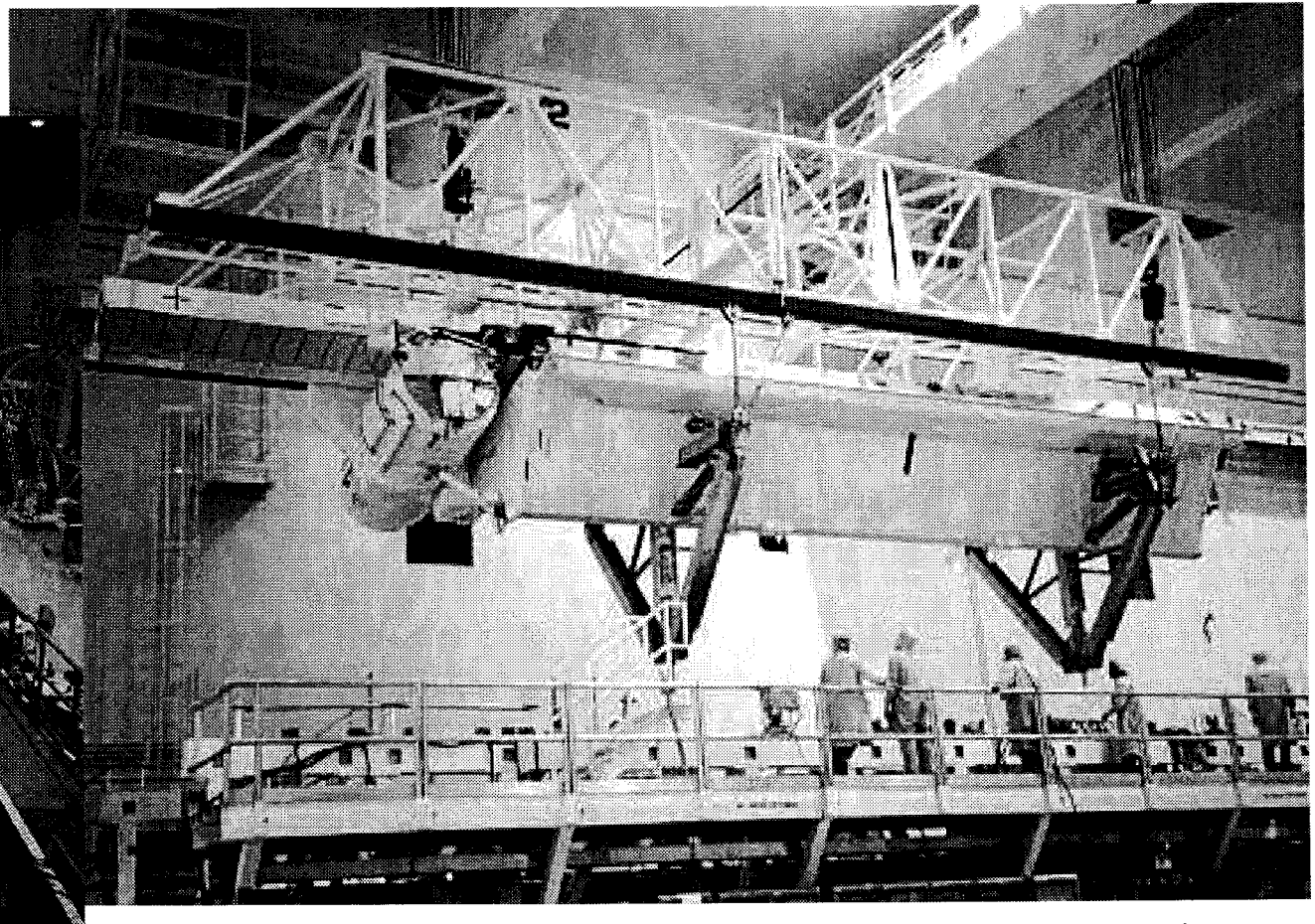
Shuttle Radar Topography Mission

Payload Bay Hardware - II





approximate view from shuttle crew cabin



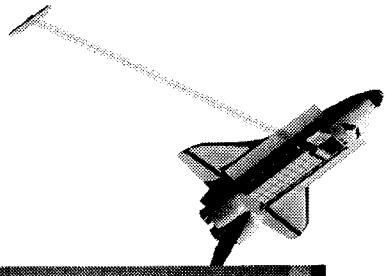
test stand (same size as shuttle payload bay)

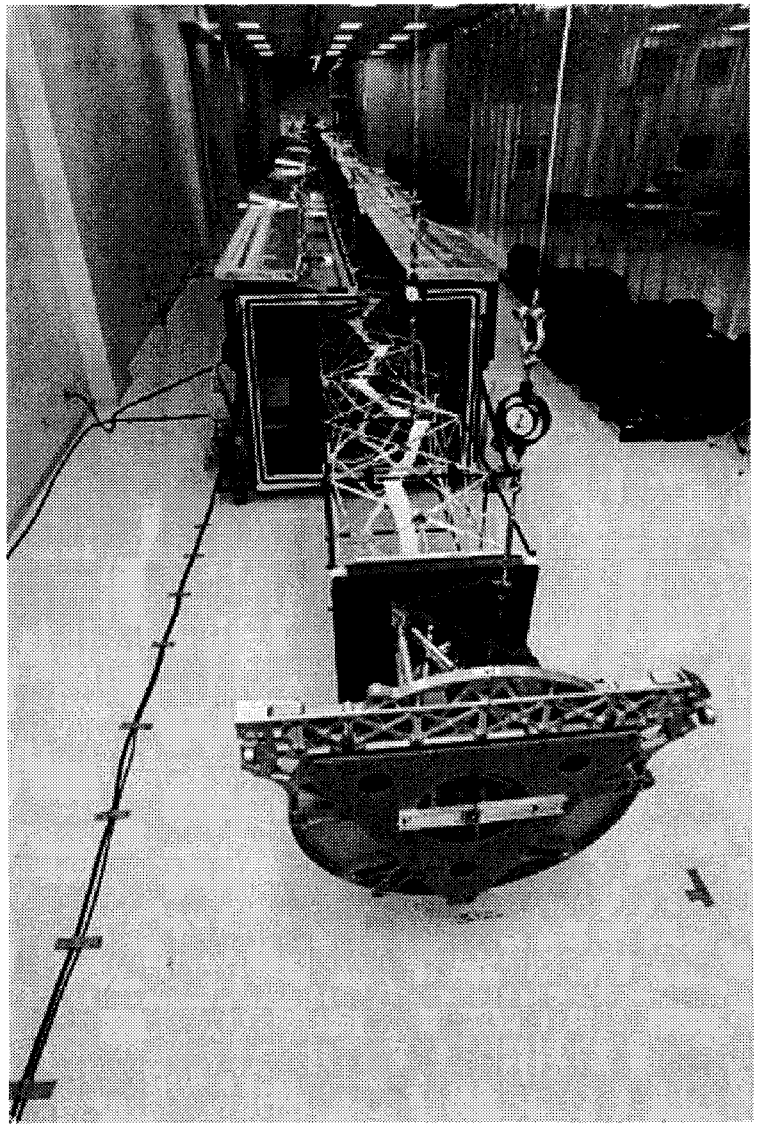
photos taken in the space-station processing facility (SSPF) - May 1999

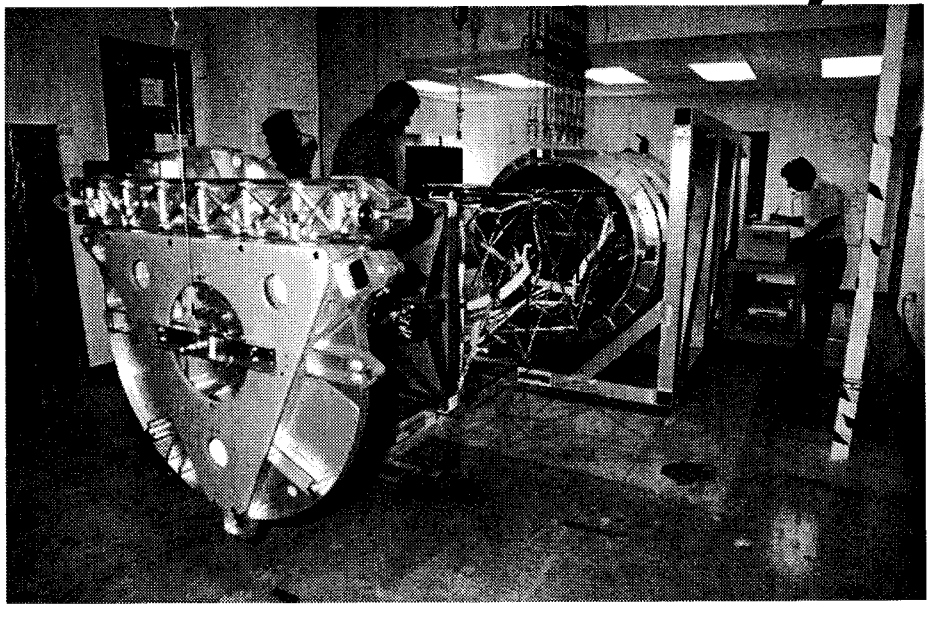
JPL DLR

Shuttle Radar Topography Mission

Mast



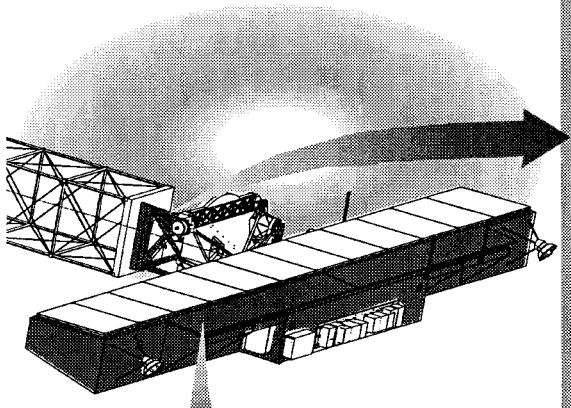


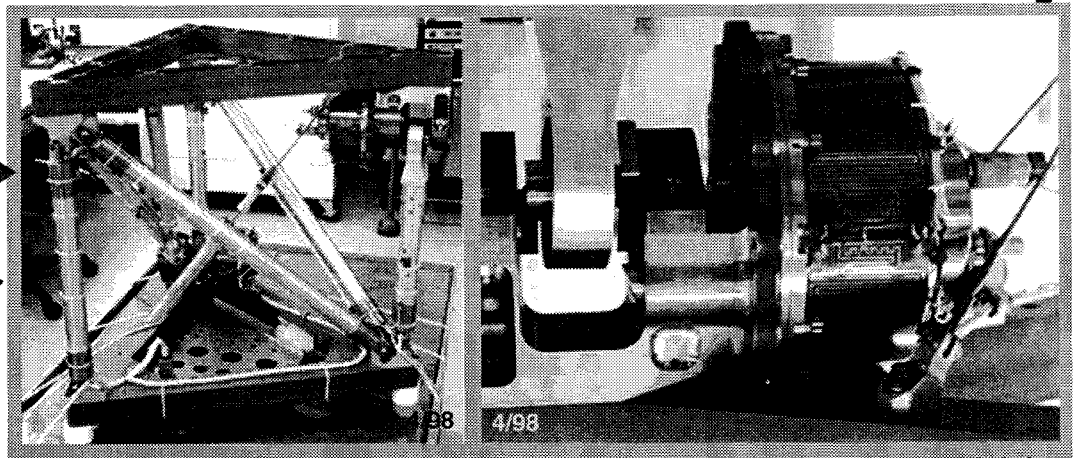


Purpose:
- deploys the 960 lb "outrigger" radar antenna
- routes wire harness, coax cables, and cold-gas hose to antenna
- provide 0.5 inch deployment repeatability

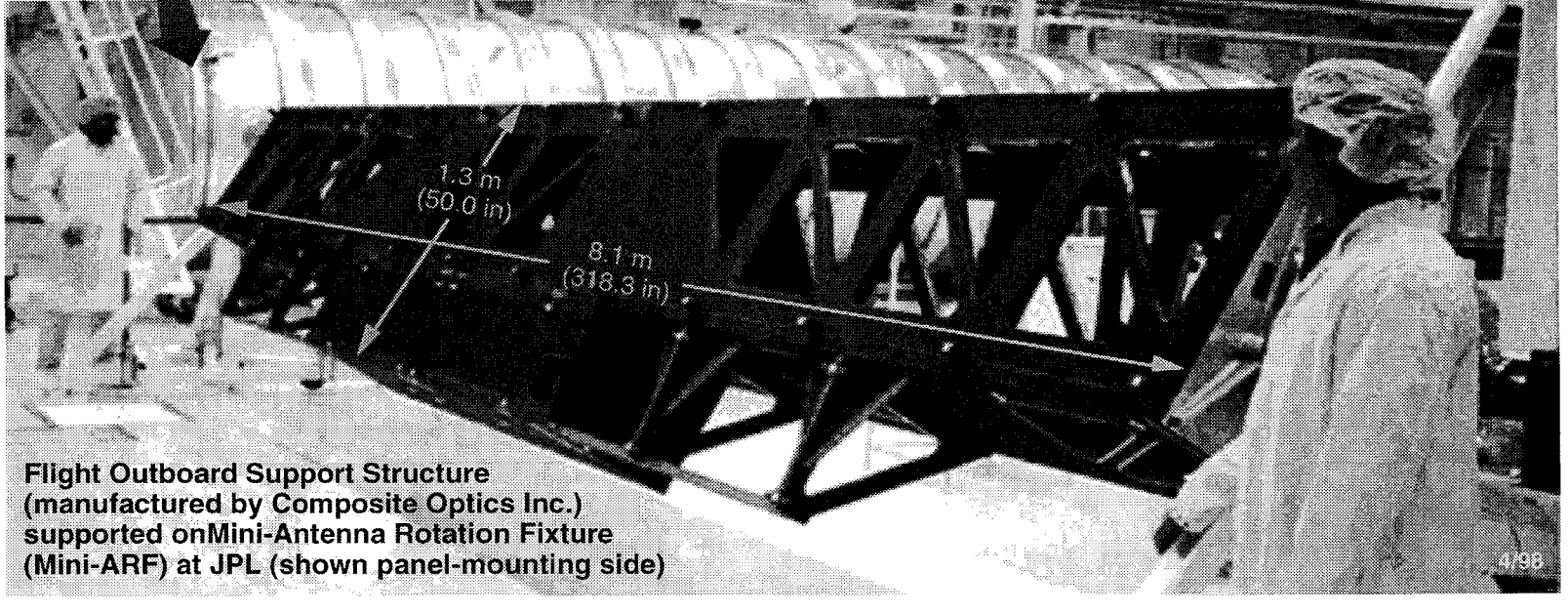
Challenges:
- safety issues associated with large deployed structure
- bending & twisting requires mechanism for antenna alignment
- cold-gas thruster at mast tip required to counteract the long moment arm generated by the mast/antenna
- control system stability issues (had to add dampers to prevent resonant instability &/or excessive propellant consumption)

Outboard Structure and Actuator Assembly



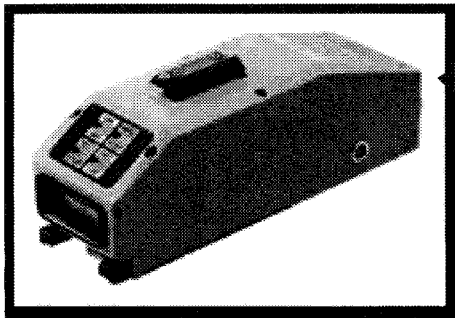


Outboard Actuator Assembly (above left) and one of the actuators (right)

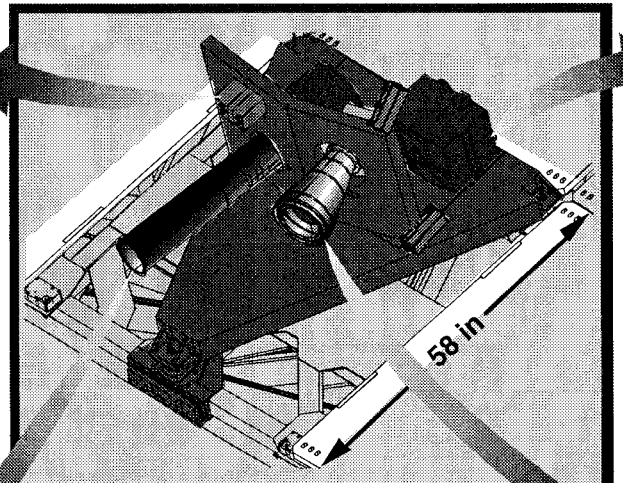


Flight Outboard Support Structure
(manufactured by Composite Optics Inc.)
supported onMini-Antenna Rotation Fixture
(Mini-ARF) at JPL (shown panel-mounting side)

AODA Electronics

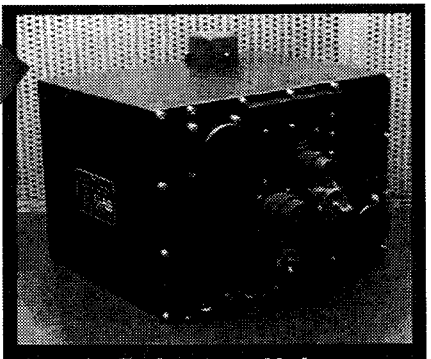


Electronic Distance Meters (x 4)
- Measures baseline distance between inboard and outboard antennas
- Leica D12002 w/ JPL qualification and packaging



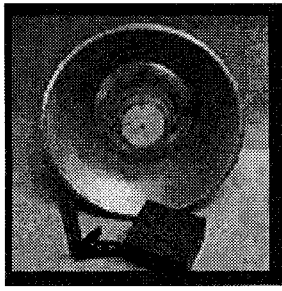
AODA Sensors on Inboard Plate

- *AODA provides precision baseline metrology and platform attitude and orbit determination necessary for post-flight SRTM height reconstruction*
- *AODA provides engineering data for inflight operations*



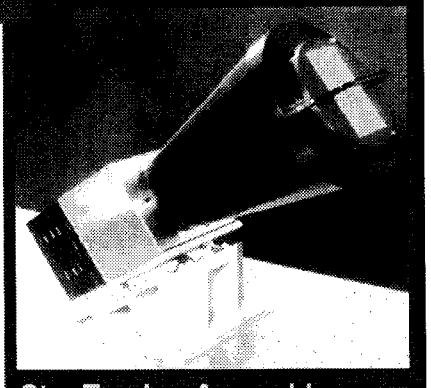
Inertia Reference Unit
- Measures attitude change of inboard platform
- Teledyne Dry Rotor Inertial Reference Unit (DRIRU-II); flown twice

ASTROS Target Tracker
- Track LED's on the outboard antenna to determine baseline attitude
- JPL-developed; flown twice
- Mods to optics, firmware, and electronics for SRTM



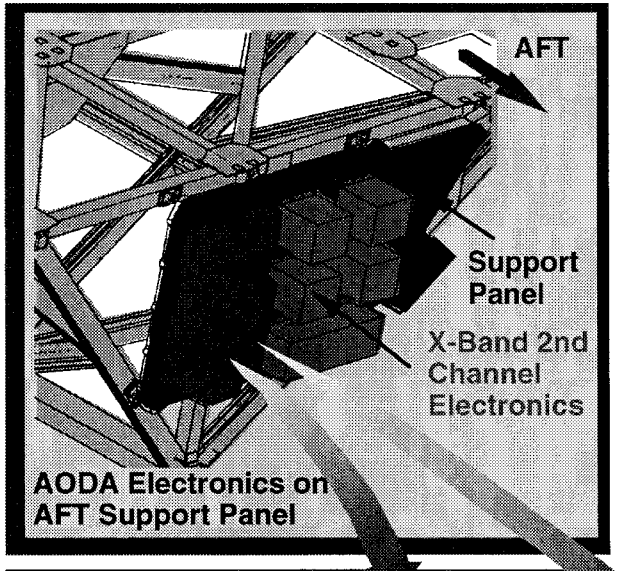
GPS Receivers* (x 4)
- Provides GPS-based position and velocity measurements
- JPL-developed "Turbo-Rogue" receiver

*Antenna/LNA shown

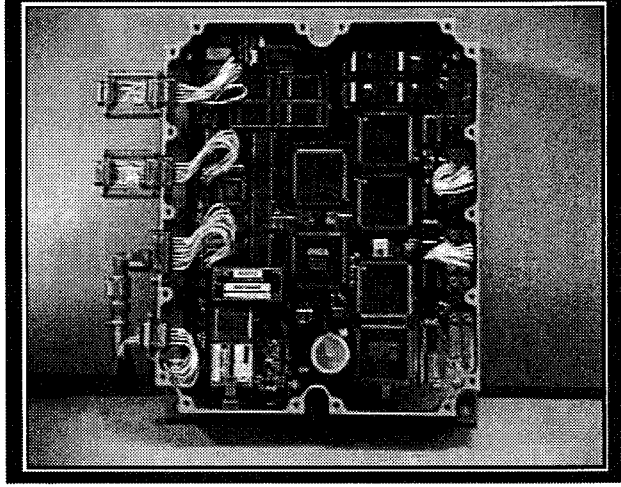


Star Tracker Assembly
- Measures absolute attitude of inboard platform
- LMMS AST-201; nearly identical to unit delivered to NMP-DS1

AODA Electronics (cont'd)

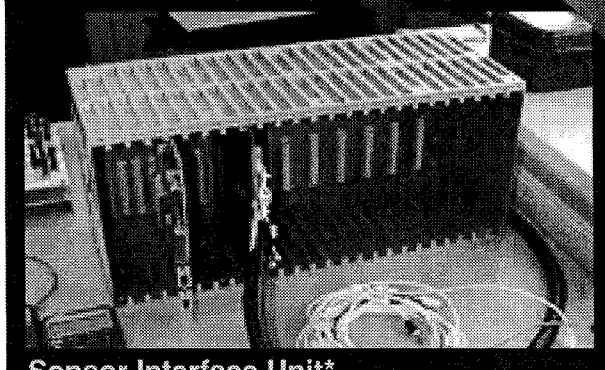


AODA Electronics on AFT Support Panel



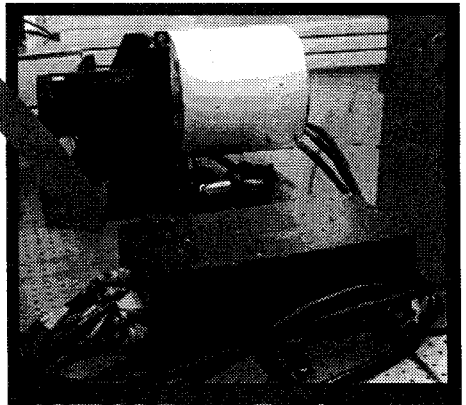
GPS Receivers* (x2)
- Provides flight component of "GPS" solution for SRTM position
- JPL-developed "Turbo Rogue" space receiver

* Digital slice shown

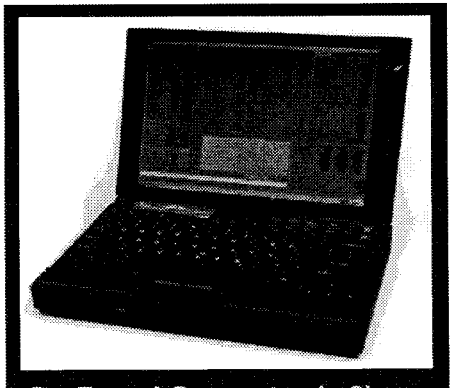


Sensor Interface Unit*
- Command, data, power and timing mux/demux
- JPL-developed

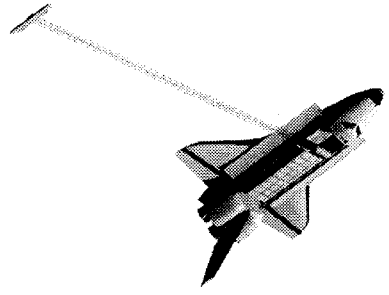
* Breadboard shown



ASTROS Target Tracker
- Tracks LED's on the outboard antenna to determine baseline attitude
- JPL-developed; flown twice



On-Board Computer (x 2)
- Controls sensors, process and archive data
- IBM Thinkpad 760 w/ mod.
- JPL- developed SW
- Located in crew cabin



AODA GPS Receivers

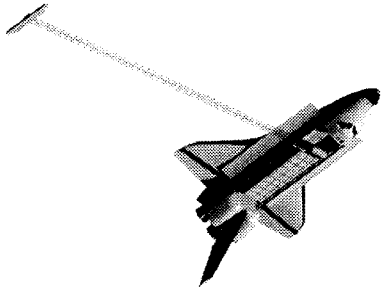
- **requirements:**
  - provide shuttle state vector good to 1 meter & 5 cm/s (1.6σ)
  - provide 100 μs time-tags to sync position solutions with radar data (avoid pixel registration errors due to along-track velocity)

- **JPL-developed "Blackjack" GPS receivers (2)**
  - based on proven "Turborogue" space GPS receivers
  - SRTM version supports 7 channels
  - tracks P1 & P2 (Y-codeless implementation)
  - provides dual freq pseudorange & carrier phase observables

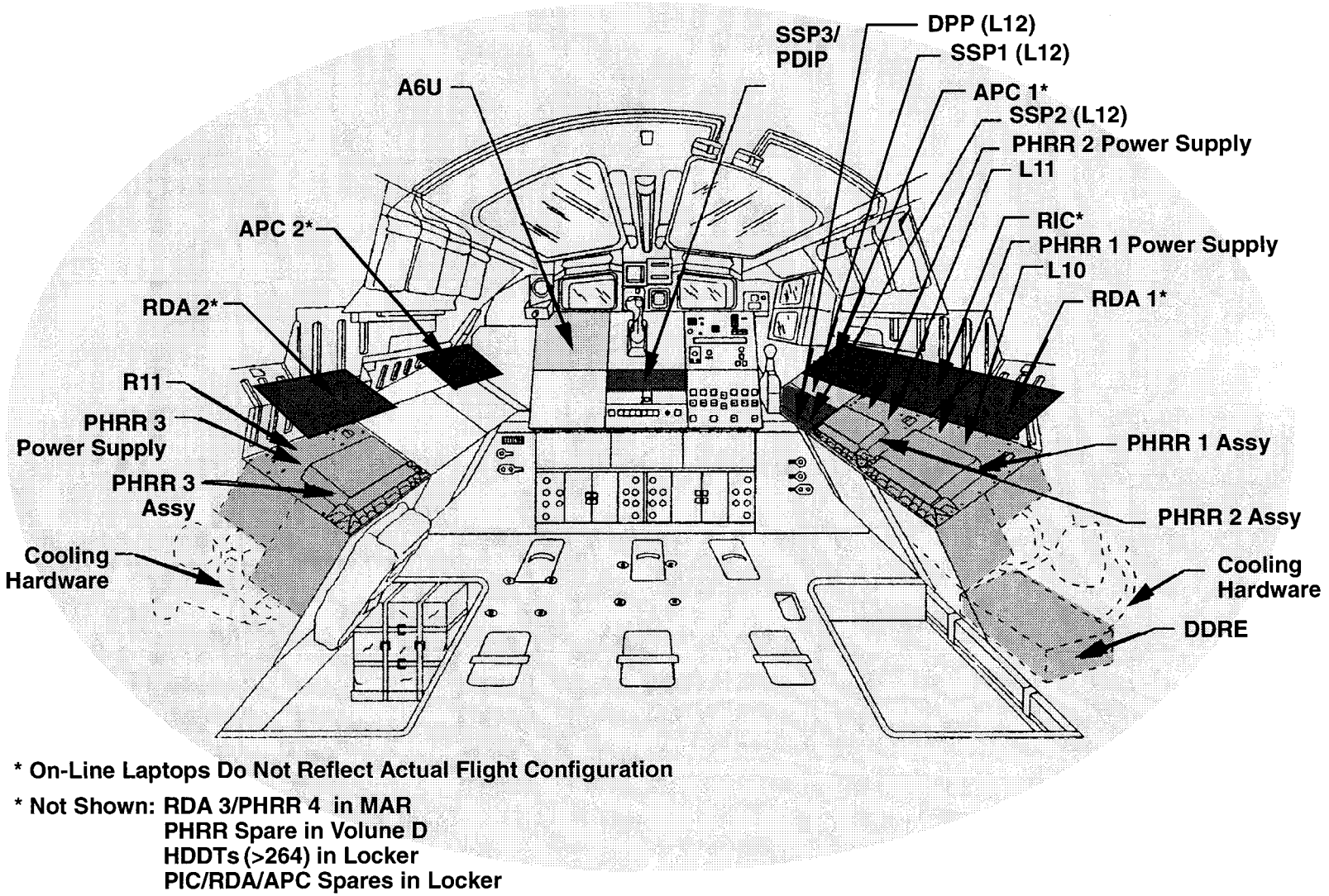
- 1 m accuracy achieved by combining onboard receiver data (post-flight) with contemporaneously archived data from international ground network of GPS receivers (i.e., global differential GPS) - based on proven TOPEX/Poseidon GIPSY/OASYS precision orbit determination experiments

- 1 μs time-stamps provided in telemetry (referenced to C- and X-band radar supplied 1 pulse per second sync signals)

- **for more details about the SRTM GPS receivers, contact:**
  Dr. Larry Young, JPL, 818-354-5018



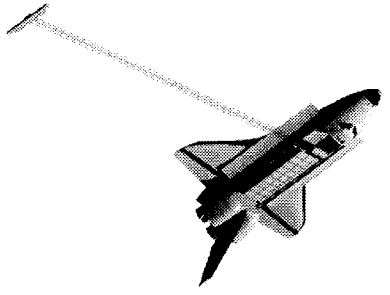
Crew Cabin Hardware



* On-Line Laptops Do Not Reflect Actual Flight Configuration

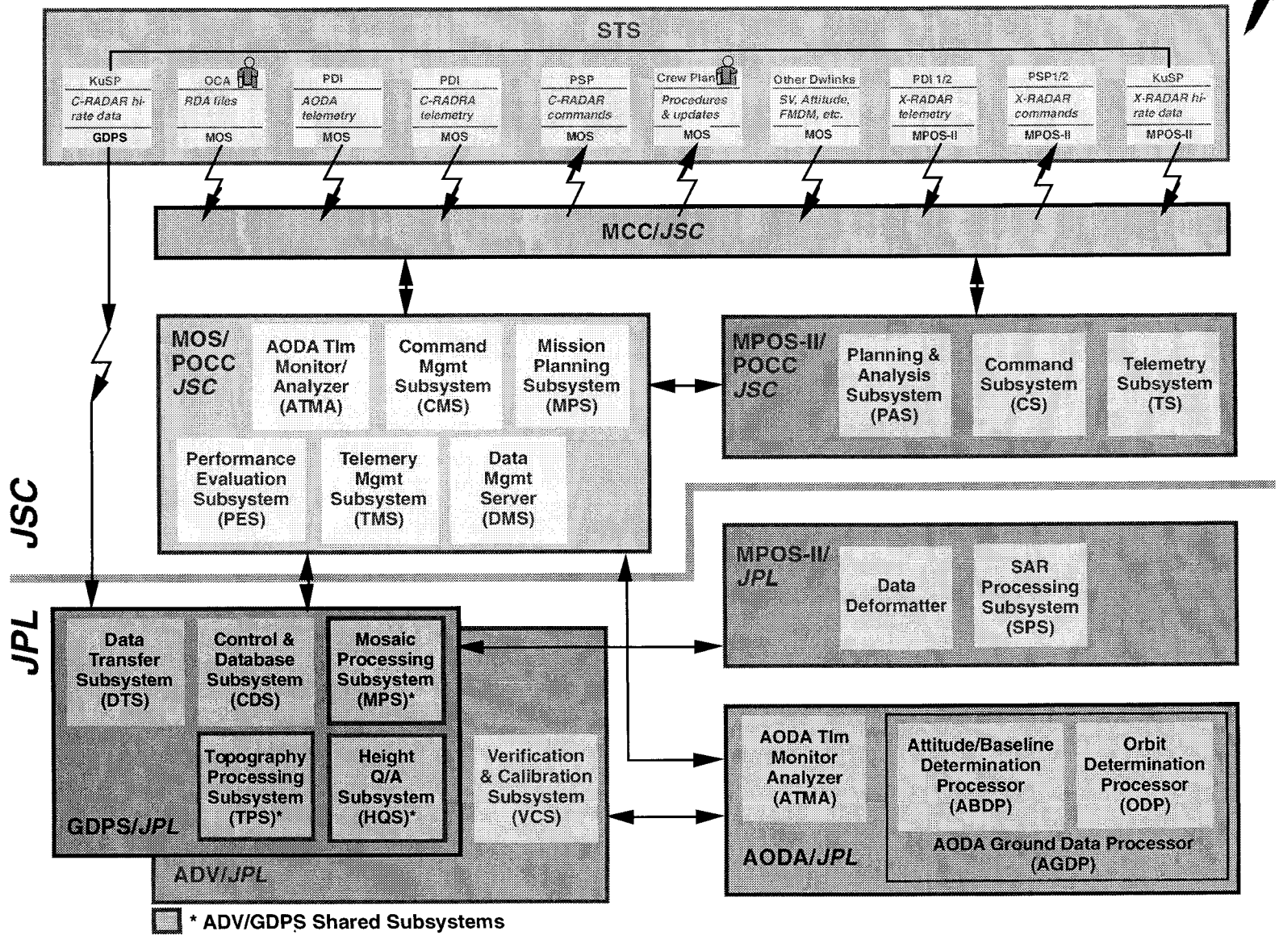
* Not Shown: RDA 3/PHRR 4 in MAR
PHRR Spare in Volume D
HDDTs (>264) in Locker
PIC/RDA/APC Spares in Locker

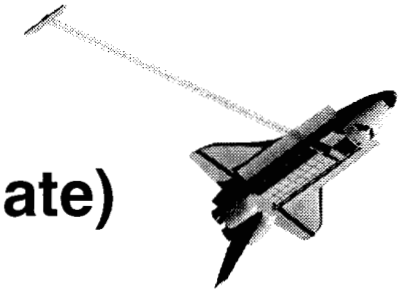
Mission Operations



- 11 day shuttle mission with 10 day s of SRTM operation
- 6 member astronaut crew (1 pilot/commander and 2 mission specialists per shift)
- ~200 personnel for SRTM ground control team
  - 50 per shift at the Payload Operations Control Center at JSC in Houston
  - 20 per shift at JPL in Pasadena
- first 12 hours dedicated to activation and checkout
- "fly cast" trim burns required once per day to maintain orbit altitude
- remaining time spent mapping (all major landmasses and islands within range plus some ocean calibration passes) ~ 80 hours total radar operation

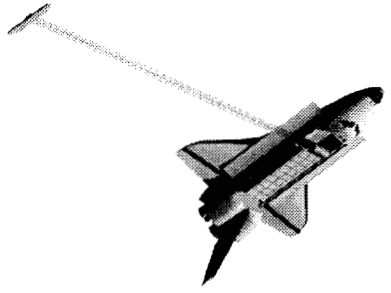
Mission Operations Subsystems





On-Orbit Checkout Timeline (approximate)

Time since launch (days/hours:minutes)	Activity
0/02:00	open payload bay doors
0/02:30	begin SRTM electronics activation (crew & ground command)
0/05:30	deploy mast & verify safe
0/06:30	flip outboard antenna
0/07:00	activate GPS & start radar checkout
0/07:30	first thruster pulse test (without dampers)
0/08:00	uncage mast dampers
0/08:30	second truster pulse test (with dampers)
0/09:00	rough antenna alignment
0/09:45	activate cold gas thruster
0/10:30	use pulse test results to confirm no control system interaction -collapse deadband
0/12:00	first fly-cast test
0/13:00	analyze radar & AODA data to determine any electrical/mechanical alignment bias
0/13:30	precision antenna alignment
0/14:30	OOCO complete - mapping begins



Summary

- SRTM will produce a uniform global (80%) topography data set twice as accurate as existing date set
  - Significant impacts in many applications, including national security and scientific applications
  - Data very useful for C and X radar interferometric phenomenology studies
- SRTM will provide global (80%) C-band and partial X-band scattering maps which can be used for large scale classification

- SRTM will be the first spaceborne fixed baseline interferometric SAR
  - Pushing state-of-the-art technologies which will lead to better design and implementation for future interferometric SAR missions
  - Advantages over repeat pass interferometry, immune to temporal decorrelation and other time dependent disturbances